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The INSTITUTION *of* PRODUCTION ENGINEERS

JOURNAL

(*February* 1944, *Vol. XXIII, No.* 2, *Ed. B*)

CONTENTS

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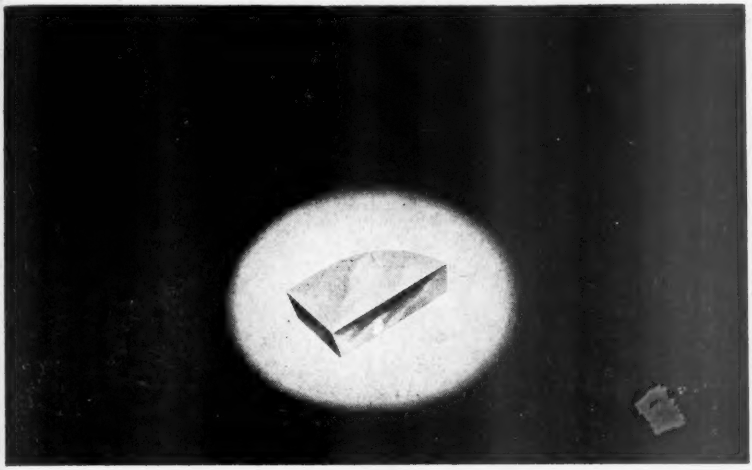

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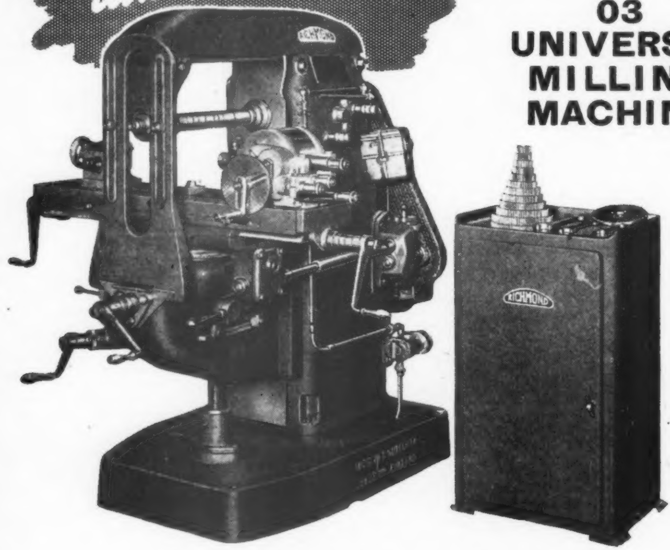

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INDEX TO ADVERTISEMENTS

As a war-time measure the advertisement section of this Journal is now published in two editions, A *and* B. *Advertisers' announcements only appear in one edition each month, advertisements in edition* A *alternating with those in edition* B *the following month. This Index gives the page number and edition in which the advertisements appear for the current month.*

The fact that goods made of raw materials in short supply owing to war conditions are advertised in "The Journal" should not be taken as an indication that they are necessarily available for export.

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1943-44

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INSTITUTION NOTES

February 1944

March Meetings.

3rd Lincoln Sub-Section. A meeting will be held at the Technical College Lecture Hall, Lincoln, at 6-30 p.m. when V. W. Bone, Esq. M.I.Mech.E., will lecture on "Production in the U.S.A."

3rd Coventry Section. A meeting will be held in Room A.5 of the Coventry Technical College, at 6-45 p.m. when A. E. Shorter, Esq., M.B.E., will lecture on "Surface Hardening (Shorter Process)." Arrangements are being made for a 30 minutes film show to precede the lecture proper. The film will commence at 6-15 p.m.

4th Yorkshire Graduate Section. A visit will be made to the works of Thos. Smith & Sons, Ltd., Rodley, Excavating Machinery Manufacturers, at 2-15 p.m. This is a joint visit with the Graduate Section of the Institution of Mechanical Engineers.

6th Coventry Graduate Section. A meeting will be held in the Coventry Technical College (Room C17) at 6-45 p.m. when G. Hayward, Esq., Grad.I.P.E., will lecture on "Application of Electrical Power to Machine Tools."

7th Western Section. A Joint Meeting with the Gloucestershire Engineering Society will be held in the Technical College, Gloucester.

10th London Section. A meeting will be held at the Institution of Civil Engineers, Gt. George Street, London, S.W.1, at 7-0 p.m. when R. Puleston, Esq., will give a paper on "The Cathode Ray Tube and Its Applications."

15th Birmingham Section. A meeting will be held at the James Watt Memorial Institute, Birmingham, at 7 p.m., when Norman Salmon, Esq., will lecture on "The Technique of Deep Drawing as applied to Automobile Pressings."

17th North Eastern Section. A meeting will be held at The County Hotel, Newcastle-on-Tyne, at 6-15 p.m. when there will be an "Engineering Brains Trust."

17th Wolverhampton Section. A meeting will be held at the Dudley and Staffordshire Technical College, Dudley, at 6-30 p.m., when H. Fairbairn, Esq., will lecture on "Design Considerations for Applications of Die Castings."

March Meetings—*Continued.*

18th Nottingham Section. A meeting will be held in Nottingham when H. Pellett, Esq., of BX Plastics Ltd., will lecture on "Plastics."

18th Preston Section. A meeting will be held at the Royal Oak Hotel, Chorley, at 2-30 p.m. when F. H. Bates, Esq., will lecture on "Hard Metal Cutting Alloys."

23rd Leicester Section. A meeting will be held at The College of Technology, The Newarke, Leicester, at 7-0 p.m. when W. L. Sims, Esq., A.M.I.E.E., A.M.I.Mech.E., will lecture on "Developments in the Electrification of Machine Tools."

23rd Glasgow Section. A meeting will be held in The Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank Crescent, Glasgow, C.2, at 7-15 p.m. when M. R. Hinchcliffe, Esq., will lecture on "Die Casting."

24th London Graduate Section. A meeting will be held at 36, Portman Square, London, W.1., at 7 p.m., when there will be a "Questions and Answers" evening.

25th Yorkshire Graduate Section. A meeting will be held at the Great Northern Hotel, Leeds, at 2-30 p.m. when F. Grover, Esq., M.I.P.E. will lecture on "The Role of Mathematics in Engineering."

26th Luton Section. A meeting will be held at the Luton Library Meeting Room, George Street, Luton, at 10-0 a.m. when A. L. H. Perry, Esq., B.Sc., A.I.C., of I.C.I. Ltd., will lecture on "Some Metallurgical Aspects of the Case Hardening and Heat Treatment of Steel."

29th Sheffield Section. A meeting will be held at the Royal Victoria Hotel, Sheffield, at 6-30 p.m., when R. H. Bebb, Esq., will lecture on "Plastic Production."

29th Manchester Section. A meeting will be held at the College of Technology, Manchester, at 7-15 p.m. when Dr. R. W. Bailey, will lecture on "Defects in Steel—their Causes, Detection and Consequences."

31st Lincoln Sub-Section. A meeting will be held in the Technical College Lecture Hall, Lincoln, at 6-30 p.m. when A. B. Lloyd, Esq. (Wednesbury), will lecture on "Production Loading Systems."

31st Eastern Counties Section. A Jig and Tool Symposium will be held. No details yet available.

31st Coventry Section. The Annual General Meeting will be held in the Coventry Technical College at 6-45 p.m.

March Committee Meetings, etc.

12th The Finance Research Committee at Nottingham, 5-0 p.m.

12th The Management Research Committee at Nottingham, 6-0 p.m.

13th The Management Research Committee at Loughborough, 10-0 a.m.

17th The London Section Committee at Institution Headquarters, 12-0 noon.

17th The Finance and General Purposes Committee at Institution Headquarters, 2-15 p.m.

24th The Council of the Institution at Loughborough, 11-30 a.m.

28th The Education Committee at Queen's Hotel, Birmingham, 10-0 a.m.

28th The Membership Committee at Queen's Hotel, Birmingham, 12-30 p.m.

The Technical and Publications Committee meets at Institution Headquarters every Wednesday at 5-30 p.m.

Research Department Appeal.

The Council of the Institution has decided to launch an appeal on behalf of the Research Department, and it is hoped to obtain the sum of £5,000 which is required to enable the Department to expand its activities.

The Council gratefully acknowledge contributions which have been received during the current financial year from the undermentioned firms and members :—

	£	s.	d.
Jones & Shipman, Ltd.	100	0	0
Frank Guylee & Son, Ltd.	10	10	0
Associated Equipment Co. Ltd.	100	0	0
Weir Precision Engineering, Ltd.	50	0	0
Machine Tool Trades Association	1,050	0	0
E. Pryor & Son	20	0	0
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Mr. Norman Davies, A.M.I.P.E.		10	6
Mr. J. C. Kerr, Int.A.M.I.P.E.	5	0	0

It is with great pleasure that we announce the receipt of one thousand guineas from the Machine Tool Trades Association, who have intimated their desire to offer the fullest support pos-

sible to our Research Department, and to our efforts to obtain official recognition by the Department of Scientific and Industrial Research.

Addresses Wanted.

Considerable difficulty is being experienced by lack of information concerning the whereabouts of the undermentioned members. If any member who has knowledge of these addresses will they please advise Head Office.

V. C. Allix, A.M.I.P.E.
John Barclay, Grad.I.P.E.
Hanus Bloch, Stud.I.P.E.
G. Buckle, A.M.I.P.E.
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C. E. Day, A.M.I.P.E.
James W. Foley, A.M.I.P.E.
Albert F. C. Foster, A.M.I.P.E.
V. France, A.M.I.P.E.
Lewis J. Fry, A.M.I.P.E.
Monte Gaunt, Stud.I.P.E.
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Charles Hunter, A.M.I.P.E.
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H. D. Jarvis, Grad.I.P.E.
A. C. Ledingham, M.I.P.E.
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A. D. MacIntyre, A.M.I.P.E.
Eric Mells, Grad.I.P.E.
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F. C. Shelley, Grad.I.P.E.
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James Wakefield, M.I.P.E.
B. H. Wakeman, Grad.I.P.E.
Albert J. P. Warwick, M.I.P.E.
E. W. White, A.M.I.P.E.

Obituary.

We deeply regret to learn of the death of the following members of the Institution:

Mr. J. H. Southcott, A.M.I.P.E.
Mr. G. T. Sjogren, M.I.P.E.
Mr. T. H. Hallam, A.M.I.P.E.
Mr. H. Lythe, A.M.I.P.E.
Mr. F. M. Bellwood, M.I.P.E.
Mr. J. Tillotson, A.M.I.P.E.

Organisation and Control of Factory Production.

In the December *Journal* we published an article presented to the Institution by the Associated Equipment Co., Ltd., who have asked us to make the following reference to it :

" With reference to the booklet on The Organisation and Control of Factory Production, the Associated Equipment Co., Ltd., point out that in emphasising the importance of spreading knowledge of Production Control methods, they are largely indebted to the

inspiration gained from the arguments of Mr. T. G. Heckels, M.I.P.E., for the main lines of the arguments laid down in the introduction to the booklet. As it is perhaps not yet sufficiently known, Mr. Heckels dealt with these problems on similar lines in papers and lectures as long ago as 1931 and 1932."

October Journal.

Will any member willing to spare his copy of the October, 1943 *Journal* kindly forward this to Head Office.

BOOK REVIEW

The Extrusion of Metals, by C. E. Pearson. Published by Chapman & Hall. Price 18/-.

While this book may not appeal to all Production Engineers, it will prove very valuable to all those concerned with the production or use of extruded metals.

It is a most useful summary of the available information by one well versed in his subject. It is sound, well written, and forms an extremely comprehensive survey of the subject.

W.H.T.

POWDER METALLURGY

Paper presented to the Institution, Coventry Section, on 5th November, 1943, by W. D. Jones, M.Eng., Ph.D.

THERE is one thing I would like to say immediately and that is that this lecture would be very different in peace time. A considerable amount of development work on powder metallurgy is progressing in this country and the greatest proportion of this is intimately connected with war work. As also is very common with new subjects, most of the firms engaged upon development work, for one reason or another, prefer to keep their developments on the secret list. I am afraid, therefore, that I shall have to limit my remarks this evening very severely to information of more or less a general nature. Probably, however, it will be possible in the discussion to deal with any points of more particular interest to any of the audience.

I propose indicating first what powder metallurgy is and what are its typical products. I shall then indicate something of the typical physical properties which are nowadays attainable by powder metallurgy, and finally I would like to try and give some guidance to any manufacturer or technical man in the audience who is interested in the subject and who may like to commence production or experimental work.

Powder Metallurgy can be considered simply as an art of making metallic articles or masses by moulding powdered metals. It bears very close resemblance to the plastics trade and follows in many respects much of the technique used in plastics.

Broadly, the technique consists in commencing with powdered metal, or alloy, or mixture, of a fineness generally less than 100 mesh. (In a 100 mesh sieve the aperture is 1/200th of an inch and consequently the largest particle that will go through a 100 mesh sieve is less than 1/200th of an inch in its largest diameter). I have here a variety of powders typical of those which are used. The powder, or mixture of powders, is inserted into a die and pressed under anything from 5 to 100 tons per sq. in. pressure, forming a moulding, or pressing, or compact, which is the word generally used in this connection, which is then ejected from the die. With all suitable commercial powders this pressing stage produces a solid coherent compact at least sufficiently strong to permit of moderately rough handling, although without any real physical strength. The porosity of such a compact is generally more than 10% and may be

as much as 50%. Its strength is due to the mechanical interlocking of each particle and to the cold welding that has taken place between each particle. The compact is now heat treated, or sintered, by passing through a furnace at a temperature generally of the order of two-thirds of the melting point of the metal or alloy, but this temperature is frequently higher than this although always below the melting point. Normally the compact is protected from

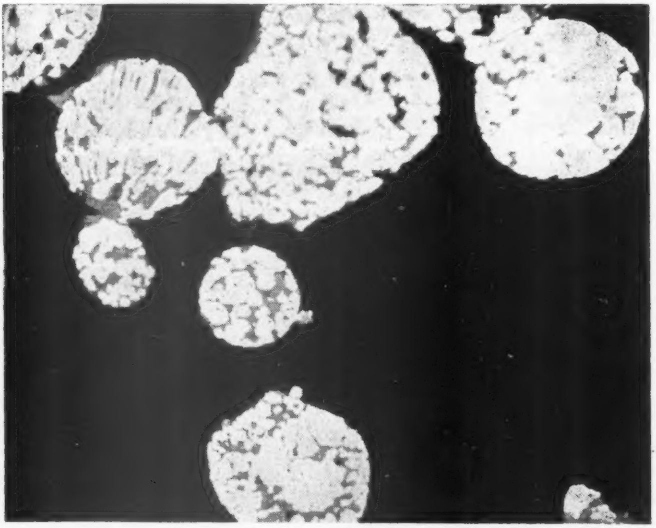

Fig. 1.—Photo micrograph of a 200 mesh copper-lead powder (40% lead). Magnification 600

oxidation by maintaining in the furnace a suitable reducing atmosphere, although in some cases good results are obtained by sintering in air or in a neutral atmosphere. During the sintering stage actual welding of the various particles of metal takes place and the aggregate adheres into a strong mass which may, under favourable circumstances, have physical properties approaching those of the cast or forged metal.

During this sintering operation there is normally some change in the dimensions of the article, either an expansion or contraction, and frequently this change is not uniform so that in addition to dimensional changes there may be actual shape distortion. As far

as possible these changes are kept within very small limits and in many cases this can be done to an extent so that on cooling after heat treatment the manufacturing process is now finished. Where this is not possible, however, and when particularly close dimensional tolerances are desirable, the article may be re-pressed in the die, or coined, which is the customary term, and the final dimensions or shape are thus impressed upon it. This technique, as I have just described, is the normal and customary process of manufacture and I will refer to it as the cold-pressing technique. Recently, however a considerable amount of work has been undertaken and some commercial production has been put into operation, both in America and in this country, along a modified technique in which pressure is applied to the compact whilst it is hot and at its sintering temperature. This method is known as the hot-pressing technique and gives compacts with substantially different physical properties from those obtainable by the cold-pressing technique. I shall deal in more detail with this aspect of the subject shortly.

From what I have just described of these elementary stages of manufacture it is possible quickly to form some appreciation of the advantages of powder metallurgy in comparison with the more normal methods of producing metal articles by casting or forging. Firstly, one has to appreciate that in producing a metal mass by casting one has to be content with obtaining in the metal only those physical constituents which can be produced by crystallizing from the melt. Metallurgists are so familiar with cast and forged structures in metals that I frequently feel they do not as a rule fully appreciate the very marked limitation which casting enforces upon the choice of physical constituents in an alloy. Perhaps I can make this more clear by indicating that in a mass of metal prepared by powder metallurgy it would be quite possible to mix together and press and sinter various selected phases out of various alloys which one could not possibly obtain together in a cast metal. For example, just taking a hypothetical case one might blend together say the copper-tin intermetallic compound of the bronze alloys with a proportion of cementite out of the iron carbon system and embed the mixture in a ground mass of nickel. I am not saying for one moment that such an agglomerate would be of any practical use but I am putting this forward as an idea of the type of thing which could be done by powder metallurgy and which would be impossible by casting. One should appreciate also that the same technique permits the mixing and compacting together of mixtures of metals and alloys with non-metallic materials, such as graphite, abrasives, lubricants, and so on. One of the outstanding advantages of powder metallurgy is, therefore, that the range of physical constituents obtainable in an alloy or aggregate is vastly greater than that coming within our present-day range of knowledge by casting.

Metallurgists are only just beginning to get an inkling of these possibilities and undoubtedly within the next ten years or so all our present-day commercial alloys will have to be re-examined from the point of view of whether it is possible to introduce into them new and beneficial constituents. There are other obvious advantages of the powder metallurgy technique. One is that there is no wastage of metal. In producing articles by casting there is always very heavy scrap loss in the form of headers, risers, and so on, and even in later stages of rolling or stamping out of sheet there is frequently a heavy scrap wastage. This is, of course, entirely avoided by powder metallurgy.

Another aspect in which powder metallurgy is particularly interesting nowadays, in war time, is the fact that it is frequently possible to press articles finished to size and shape within close tolerances, and thus to avoid a considerable proportion of machining operations. Of course, one might say that such a claim is equally possible for die-cast articles, but I should point out that die-casting in the field of ferrous alloys is not at all feasible at the present time. Arising from this advantage is the saving in skilled labour because powder metallurgy operation permits the manufacture of the finished part by comparatively unskilled labour which might otherwise require high grade skilled machinists. It will be seen, therefore, that the powder metallurgy technique, apart from permitting manufacture of articles having properties unobtainable by other methods, has some considerable possibility in producing finished articles with a lower manufacturing cost than by customary methods. Perhaps I can give you an example which illustrates these advantages very clearly. I will take the case of the precious metals—gold and silver—because one can talk about these fairly freely without fear of giving away military secrets. Let us take, for example, the manufacture of silver coinage. The present-day method involves a very large number of steps. As far as the silver is concerned, commencement is made with impure silver bullion which is electrically refined to produce pure silver cathodes. These cathodes are then melted down into ingots by the silver refiners. These ingots are then delivered to the Mint and melted again and alloyed with copper and cast into billets. The billets are then rolled out by a number of successive rolling operations into the form of strip. Out of the strip are punched coin blanks and finally the characteristics of the coin are impressed upon the blanks. Consider the large number of operations involved in this process of manufacture! There are at least two melting operations, involving considerable expenditure of heat and power and a considerable number of intermediate rolling operations, also involving considerable power and labour, some of which is skilled. Now in comparison with this, the powder metallurgy technique would be as follows: Out of the

electrolytic silver refining bath would be taken directly, not solid silver cathodes but silver powder ready for use. In a similar way copper powder is obtained. These two powders would then be mixed together in the correct proportions and pressed in a die, the coin blanks would then be sintered and finally the character of the coin produced in a final coining step, Note immediately that in this powder metallurgy technique two melting operations are entirely avoided and there is only one heating operation at a comparatively low temperature. There are no strip rolling steps and there is absolutely no wastage comparable either with that associated with casting, or with the punching of the blanks out of the strip. There is also considerable all round saving in labour. I think I should have made it clear, therefore, that this type of operation in the manufacture of coinage, and, of course, in any other comparable article, leads, or should lead, to markedly cheaper production costs. The same technique, however, again considering precious metals as our example, would permit of one obtaining articles having characteristics which one could not obtain at all by casting methods. For example, either in the case of silver alloys or in gold alloys, it is easily possibly purely and simply by modifying pressures and temperatures, to obtain porous masses. When I say porous I would not like you to imagine I am talking about porosity such as one has in a sponge. It is easily possible in either silver or gold alloys to produce masses or articles having the porosity so fine that it is quite invisible to the naked eye. Thus remains the possibility of producing gold articles such as rings, jewellery, etc., or silver base articles such as knives, forks, etc., having a density substantially lower than that of the normal solid article. It would be possible, for example, to produce a gold ring which could be certified as 22 carat gold but which was only half as dense as the normal article, and because of that and also because of the cheaper methods of manufacture, at a very substantially lower selling price. These two illustrations should give, I think, a rough idea of the reasons why powder metallurgy as a technique is going to have a very promising future. Perhaps I should balance this by pointing out that the technique also has its limitations. For example, one can only manufacture an article of a pressable shape and this is a very severe limitation, very much more restricting than that imposed by, for example, die-casting, although one should remember that it is frequently economical even to produce a blank by powder metallurgy and finish off producing some shape by forging or drop-stamping operation, or even by following with a certain amount of machining. This limitation also applies to a considerable degree to the plastics industry, but the powder metallurgy technique is not even so flexible in this respect as that of the plastics, because plastics flow readily in a die whereas metal powders exhibit considerable frictional forces and can hardly be made to

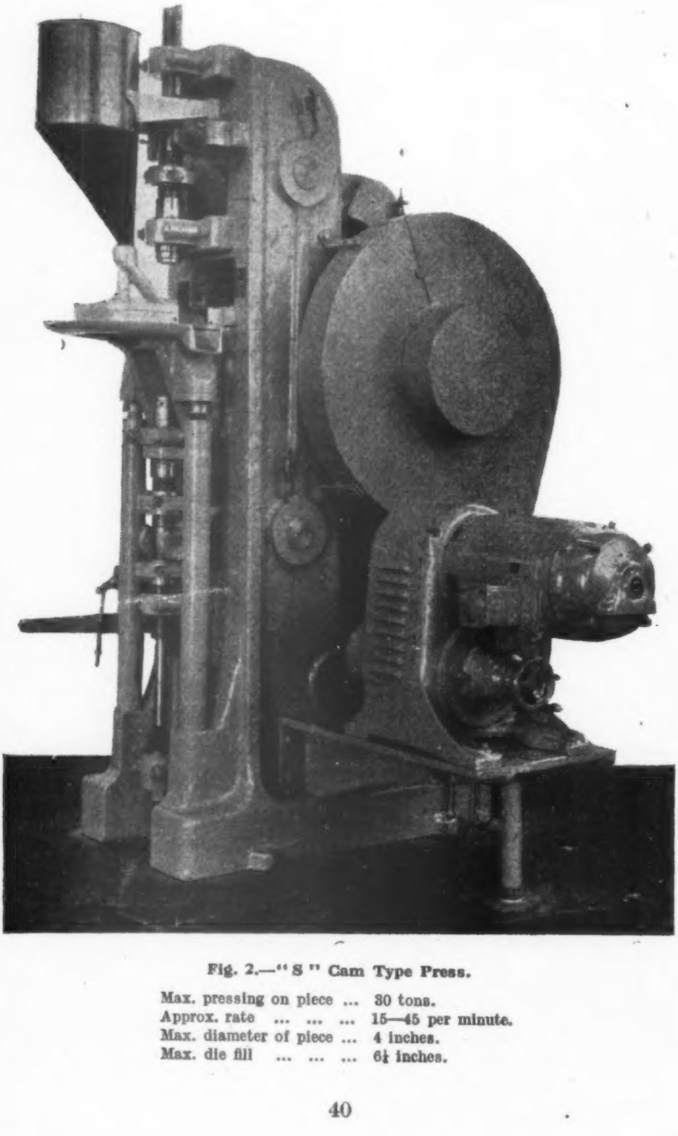

Fig. 2.—" S " Cam Type Press.

Max. pressing on piece ...	30 tons.
Approx. rate	15—45 per minute.
Max. diameter of piece ...	4 inches.
Max. die fill	6¼ inches.

flow at all, so that it is impossible, at least at present, to produce articles having undercut portions, or to produce articles finished with a screw thread. This limitation also, for example, prevents the manufacture of pressings having extremely thin sections in the direction of pressing. There is also at the present time a very definite size limitation, if the parts are to be produced in large numbers from comparatively inexpensive equipment. There is no real upper limit to size provided sufficiently large presses are available, but large presses and large dies represent very heavy initial capital expenditure and very large numbers of articles have to be produced to work off this initial expense. Finally it can be said that one of the most important limitations at the present time is that the subject is not yet sufficiently well known or understood, and that there is not enough of it at the moment being practised, with the natural result that there is a shortage of the necessary raw materials and also an absence of that necessary background or pool of experimental knowledge from which production engineers can draw.

I should now like to run quickly over a list of the various articles which are now actually being made by powder metallurgy in order to give you some idea of the range and scope of the technique. First we will consider porous materials deliberately manufactured so. The most well known is the porous bronze bearing which is extensively employed in all fields of engineering, particularly in automobiles, aeroplanes, tanks, electric clocks. sewing machines, refrigerators, vacuum cleaners and so on. It would require a most extensive list to cite all its applications and these bearings are now made in millions. They excel in circumstances where normally lubrication is difficult or perforce infrequent. Their constitution is normally a 90/10 bronze, sometimes with graphite added, with a fine porosity of between 25 and 40% by volume which is filled with lubricating oil. In many cases the amount of oil which they contain is sufficient to last them for the length of their natural life, although, of course, they can be fed with oil in the normal way, in which case the pores act as a filter for solid impurities. They are marketed in a wide range of standard sizes and the American technical press has recently stated that such bearings up to 60 lb. in weight are now being manufactured. It is wrong to imagine that these bearings are suitable only for very light loads. Particulars of suitability to requirements can, of course, be obtained from the manufacturers but as an indication one can consider the formula quoted by the Bound Brook Bearings (G.B.), Ltd., namely, $PV = 50{,}000$ where P is the load in pounds per sq. in. on the actual bearing area and V—shaft velocity in feet per minute. Porous bearings are also being manufactured from iron powder and a mixture of iron and copper. On much the same lines porous compacts are being manufactured and sold as filters for various solutions. Their composition includes bronze, cupro-

nickel alloys and nickel. A number of very important war applications have recently been found for such porous metal filters. Porous metal in the form of pellets is also used as a catalyst.

Powder metallurgy has also entered into the field of non-porous bearings. It has been found that powder metallurgy is a most excellent method of manufacturing copper-lead and copper-tin-lead bearings. The author has given a description of this subject in the October issue of *Metallurgia* which may interest the audience. Apart from simple copper-lead bushings, steel backed bearings of this type are being manufactured both in America and this Country by sintering a layer of copper-lead or copper-tin-lead powder on to a steel backing. The General Motors Corporation have published an account of a much more elaborate bearing of this type consisting of a sintered copper-nickel sponge bonded on to a steel backing and subsequently impregnated in vacuum with a molten lead base bearing alloy.

In the field of semi-porous or more or less non-porous materials comes the extensive range of iron components which are being manufactured in the United States and to a limited extent in this Country from ferrous powders. These parts have hitherto been almost entirely employed in non-stressed or very lightly stressed positions, and have been particularly popular just before the war in automobiles. The most well-known example is a small gear used to circulate the oil in a General Motors' Car. In the past this gear was machined from a cast blank at considerable cost. The powder metallurgy job is not only cheaper in manufacture but is in every way superior from the point of view of physical properties. It is difficult to itemise with any accuracy exactly what parts are being made at the present time in America from ferrous powders but as an indication the following has been published listing some of the parts produced in 1942 by General Motors and Chrysler : Thrust washers, fan bearings, oil pump gears, levers, cross heads, cams, automotive splined jack nuts, Gyrator gear sets, bearing retainers, indexing discs for dividing heads and various aircraft components such as instrument parts, engine-mount parts, carburettor shafts, pulleys, bomber turret parts, propellor parts, etc. To a limited extent a number of steel parts are being made in America by hot pressing. I shall give some description of this shortly.

There is a very wide range of special property non-porous articles made by powder metallurgy. I shall mention some of the more well known such as the nickel-iron-aluminium magnet. Alloys of this type are most difficult to melt and cast free from defects, particularly in view of the fact that they are so frequently required in very small sizes. In addition the cast alloy is mechanically weak and easily broken in shaping and is too hard to be machined

other than by grinding. Approached from the standpoint of powder metallurgy it is a comparatively simple proposition and although there is some doubt concerning whether the magnetic properties are so satisfactory as with a cast magnet, there are outstanding balancing advantages from the powder job. In the first case no casting method can approach the degree of accuracy with which the composition can be controlled by powder metallurgy. Secondly the sintered magnet does not suffer from coarse crystalline growth which renders the cast magnet so weak. Thirdly the sintered magnet does not suffer from typical casting defects such as blow holes, cold shuts, cracks or segregation of impurities to the grain boundaries, and lastly the dimensions of small sizes can be very closely controlled and any grinding that may have to be undertaken is very much less than that associated with the cast magnet.

Contact Materials.

The modern contact material is a very fine example of powder metallurgy. Successful electrical contact materials are required to possess a formidable range of qualities. They should embody in the one alloy high electrical and thermal conductivity, high melting point, high hardness and wear resistance, low contact resistance, low vapour pressure, resistance to formation of tarnish films and resistance to welding and formation of pits and beads caused by arcing or transfer of metal from one contact to the other. There is no known cast metal or alloy which has any pretention of being able to meet all these requirements at one and the same time. It is possible and perfectly practicable by powder metallurgy, however, to combine together the high hardness, resistance to welding and pitting, and high melting point of tungsten or molybdenum or tungsten carbide, with the much superior thermal and electrical conductivity and contact conductivity of copper or silver, and to produce a material having the individual qualities of both. It is important to note that the two substances, although combined together in an extremely fine state of division, are nevertheless not alloyed and therefore both substances preserve their qualities uninfluenced by the other. This is a state of affairs which could only be attained by means of the powder metallurgy technique. An extensive range of such contact materials are now manufactured covering, among other compositions, tungsten-copper, tungsten-silver, molybdenum-silver, tungsten carbide-silver, silver-nickel, and silver graphite. The processess by which they are manufactured follow the standard technique of powder metallurgy and are not in any way remarkable.

In the field of powder metallurgy components which contain a non-metallic constituent there are several outstanding examples. One is the clutch facing or brake lining which has to withstand very

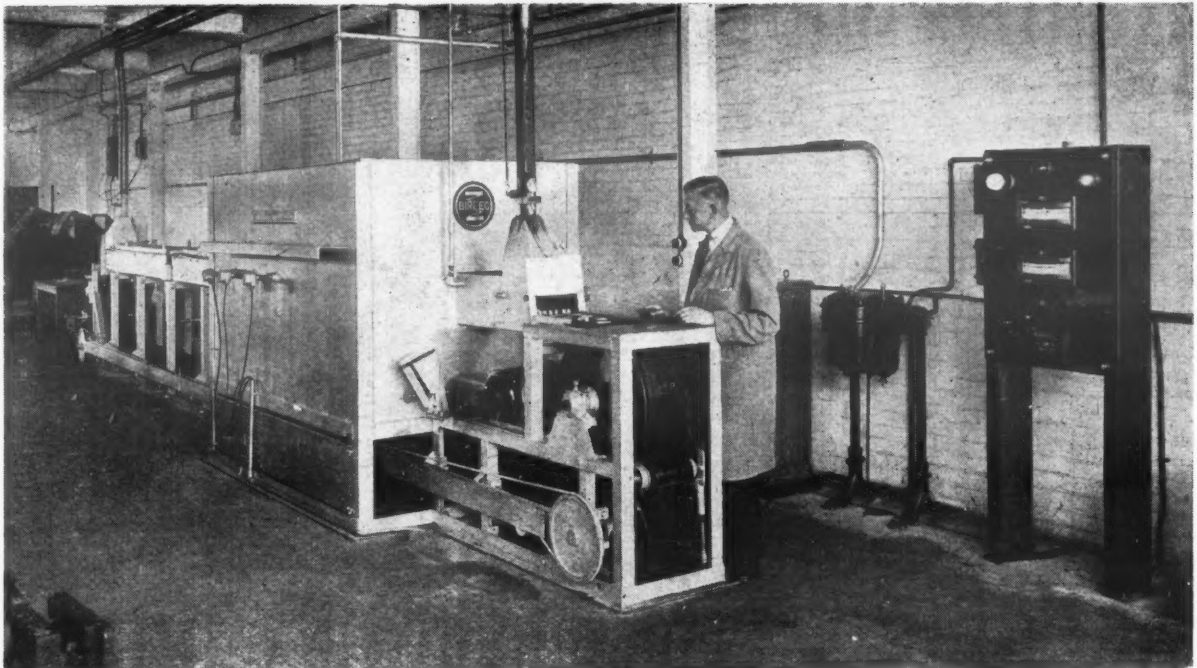

Fig. 3.—Sintering Furnace. *Courtesy Birmingham Electric Furnaces, Ltd.*

severe working conditions when fitted for example to the modern bomber. These are being made in large numbers in the United States by powder metallurgy. One example described in the press is made up of 60-76% of copper and 5-10% tin providing a ductile bronze matrix, 5-10% iron is added as a hardener and to alleviate seizing during engagement of the clutch, 5-15% of lead to provide lubrication even at high temperatures and to relieve grabbing, 2-7% fine silicon as a frictioning agent and 8% graphite as a lubricant during pressing and to provide sufficient porosity to expose the silicon granules for contact. Thin wafers of this material having a porosity of 25% are sintered and welded to a steel backing to provide the necessary structural strength. This is a striking example of an article which could not be made by any other methods.

A good case of a hot pressed metal-non metal composite is the diamond impregnated tool. These are now made in large numbers both in this country and in the United States in the form of slitting wheels, lapping wheels, rock cutting saws and rotary drills, etc.; the composition is generally bronze or iron or sometimes cobalt with a diamond content generally of the order of 25-35% by volume in anything from 400 to 10 mesh. The properties of the matrix are so adjusted that it will wear away under the conditions of usage at the same rate or very slightly faster than the diamond and thus fresh cutting diamond edges are being continually exposed.

Unfortunately many people for one reason or another have obtained the impression that all parts made by powder metallurgy are very porous and in any case must be weak. Nothing, as a matter of fact, could be further from the truth and actually both the hardest and the strongest manufactured materials are made by powder metallurgy. The hardest manufactured materials are carbide tools. A variety of compositions are employed but the simplest type consists of an extremely fine tungsten carbide powder sintered and bonded together with a small proportion of cobalt. It is a good example of how by powder metallurgy one can combine together in the one material the hardness of the hard metal particles with the toughness of the bonding metal to produce an aggregate having some of the properties of both. It is a job one could not do in any other way.

The strongest known material is probably tungsten and it is not often generally appreciated that the methods by which the refractory metals such as tungsten, molybdenum, tantalum and others are worked up are pure and simple powder metallurgy. Most of these metals can be cast but the cast product is in every way inferior to the powder product.

General experience gained with powder metallurgy and in particular with the refractory metals has shown that it is a technique which

is particularly suitable for the working up and consolidating of metals in mass (as distinct from the manufacture of articles). Over the normal processes of smelting and casting, powder metallurgy shows several advantages, in particular it is possible to control compositions with precision, it frequently permits the production of purer metals, it obviates casting defects such as blow-holes, inclusions, etc., it allows control over grain size and shape which cannot be approached by casting, and last but not least, frequently introduces a considerable saving in power and labour expenditure. These advantages are familiar to the workers in refractory metals but are only just beginning to be appreciated by the metallurgist handling the everyday metals—iron, nickel, copper, etc. It is an interesting speculation whether the metallurgy of the commoner metals will become powder metallurgy. There are indications that this is taking place and one recent example is the coalescence process for copper, which is no more than a method of extraction metallurgy for extracting and working up copper from its ores, but it is powder metallurgy pure and simple, and inasmuch as the product appears to have improved qualities with respect to electrical conductivity, ability to absorb cold work and freedom from casting defects, it is a technique which is likely to develop and extend in the future.

Having broadly covered the field of application of powder metallurgy I would like to say something about the physical properties of ordinary everyday materials such as iron, copper, brass, bronze, light metals produced by powder metallurgy in comparison with cast materials, The commercial introduction of powder metallurgy as a technique in competition with die casting or forging is quite new and has not yet progressed sufficiently far to be able to say much about what results are obtainable. Surprisingly little has been published or is known in detail about the physical properties of even the more common alloys made from powders and it remains for private enterprise or research workers yet to study the whole field of commercial alloys from the powder point of view. I cannot therefore quote much in the way of reliable figures. One other direction in which I should be cautious is to make a distinction between the physical properties of those parts actually made and sold in large numbers and of those physical properties which have been obtained experimentally in the laboratory. Considerable work by many people including myself has shown that it is possible to obtain most excellent physical properties in many metals and alloys. For example I have shown myself that there is no difficulty in making a 50 ton steel, but it may be considerable time yet before these results can be translated into commercial production. There may by several reasons for this such as, for example, absence of the right type of powders, insufficiently developed apparatus for quantity production, too high a die wear and so on. Sometimes one of the

delays is not that the job cannot be done commercially but that the firm which could do it have merely not received sufficiently big orders of any one component to justify them commencing production. I shall take care therefore to distinguish between results obtained in the laboratory and those quoted on commercial production.

Copper. Although there appears to be most interesting possibilities attached to the sintering of copper, I am not familiar with any commercial application. Entirely reliable figures for cold pressing technique have not been published but Sauerwald has reported a tensile strength of approximately 12 tons sq. in. after 6 hours sintering at 715°C. I have no doubt that this figure could be improved in commercial production. Trzebiatowski has reported unusual hardness values of 175 to 180 Brinell accompanied by good electrical conductivity in copper pressed under 200 tons sq. in. provided it is not heated above 200°C. By pressing at 275 to 300°C. under 100 tons Trzebiatowski obtained a density of 8.9 (within 1% of the calculated theoretical density) a Brinell of 160 and a specific resistance of 18 × 10—3 ohms. m.m. 2 metre. By hot pressing atomised copper powder at 940°C. I have obtained without difficulty a maximum stress of 15 tons sq. in. and an elongation of 60 %.

Brasses. Articles made by sintering brasses are understood to be in commercial production in America but no results relating to their mechanical properties have been published and no laboratory results have been puslished reporting results obtained by the cold pressing technique. By hot pressing a mixture of copper and zinc powders at 800°C. Unckel claimed a tensile of 7½ tons sq. in. which appears to be ridiculously low. By hot pressing a powdered 70/30 brass in air at 300°C. below the melting point under 5 tons sq. in. I was able to obtain a maximum stress of 15 tons sq. in. accompanied by 21% elongation.

Bronzes. Similar remarks apply to bronzes. Working with mixed powders Unckel has reported a tensile of 18 tons sq. in. and a Brinell of 131 by hot pressing at 770°C. and with a 10% bronze a tensile of 23 tons sq. in. and a Brinell of 135. Hot pressing at 800°C. with a 7% powdered alloy I have obtained a maximum stress 23½ tons sq. in. accompanied by an elongation of 75%. This is a remarkable elongation in view of the fact that the heating and pressing was conducted in air.

Light Alloys. Less has been published on the subject of pressing light alloys than anything else and this is particularly strange in view of the fact that results in this sphere appear to be most promising. I doubt if any light alloys are commercially produced by powder metallurgy but a considerable amount of laboratory investigation

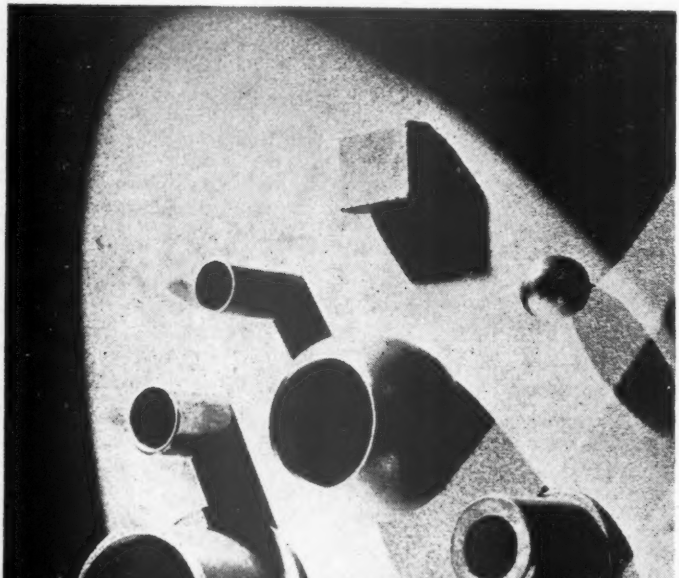

Fig. 4.—Typical metal products compressed on Stokes Tablet Machines.

Anti-friction plugs, ball sockets, knee-action, blind-end and straight thin-walled oilless bushings, ball sockets for shock absorbers, oilless bushings for telephone selector switches, oilless bearings for selective gear shift, flanged bushings and metallic motor brushes.

has been undertaken in this country. Cremer and Cordiano state that results have been obtained which compare favourably with cast or forged alloys. By the cold pressing technique with an alloy of aluminium containing 2.5% copper and ½% magnesium sintered at 610°C. for 30 minutes in nitrogen they quote a tensile strength of 40,000 lb. sq. in. Results have also been reported with a 4% copper alloy similarly treated but precipitation hardened at 188°C. for 4 hours giving a tensile of 38,000 lb. sq. in. and a 10% elongation and a Rockwell of B45. Light alloys are also known to behave excellently under hot pressing and there is little doubt that there is a considerable future for powder metallurgy in this field.

Iron. Those interested in the phycial properties of iron parts should read a valuable article on the subject in *Metallurgia*, August, 1943. A considerable weight of small parts are now being produced in iron carbon mixtures by cold pressing but the physical properties are rather poor. This is caused primarily by the necessity of using a low cost low quality iron powder and by the limit that die life sets upon cold pressures. Such parts as I have exhibited have mechanical properties similar to an ordinary grey iron. Commercially produced iron parts show, depending on the cost, a tensile from 15,000 to 35,000 lb. sq. in. accompanied either by no ductility or an elongation of less than 5%. It is probable that the immediate future will see a great improvement in the mechanical properties of commercially produced iron parts and I see no difficulty in obtaining with a cheap iron powder a tensile of over 20 tons sq. in. although without appreciable elongation. Working with more expensive and pure qualities of iron powder very much better results are possible and if sintereing is followed by forging or repressing and re-sintering then the results are excellent. Using electrolytic iron powder cold pressed and sintered at 800°C. in hydrogen Eilander and Schwalbe report a tensile strength of 18½ tons sq. in. and an elongation of 14%. Libsch, Volterra and Wulff on electrolytic iron report a tensile of 28,000 lb. sq. in. and an elongation of 14% by sintering at 850°C. By cold pressing at 33 tons sq. in. and sintering for 4 hours in dry hydrogen at 825°C. they obtained a tensile strength of 31,000 lb. sq. in., an elongation of 16½%, a density of 7.27 and a Brinell of 38.4. It by no means follows that the only scope of powder metallurgy is the manufacture of finished articles and there are considerable possibilities in using the technique simply as a producer of raw material which, after suitable mechanical treatment is subsequently forged or shaped. It is interesting to note that Koehring reports results in which a decarburised steel powder with 0.25-0.35% added carbon was pressed and sintered and hot forged in a die and slowly cooled. Tested on a standard 5 in. test piece the density was 7.1, tensile strength 73.300 lb. per sq. in., yield point 51,200 lbs. sq. in., elongation 23% on 2 in. and 32%

reduction of area with a Rockwell of B 74-85. Such a technique is entirely a commercial proposition and it is a mistake to consider that hot pressing is not feasible on an industrial scale. Excellent mechanical properties are easily obtained on quite ordinary powdered materials. For example, working with coarsely powdered steel turnings in the production of a bearing lock sleeve on a Chevrolet car, cold pressing followed by sintering at 1050°C., and then hot forging gives a material claimed to be three times as strong as a cast iron. In a somewhat similar manner, working with a powdered cast iron or normal composition hot pressed at 1000°C. I have been able to show tensile strengths as high as 36 tons sq. in.

Perhaps now it would not be out of place if I were to presume to attempt to give some advice to anyone here who might like to commence manufacturing in powder metallurgy. Although there are very few firms actually engaged in manufacture in this country at the moment, there are nevertheless a large number of concerns which are actively interested in investigating the subject and in the course of my consulting work at the present I have to advise something like one, two, three or four people each week on the subject of how to begin. The situation in most of these cases is fairly similar and therefore I feel that it might be possible to generalise the type of advice which I offer in the circumstances. The principle handicap under which nearly everyone suffers is the lack of technical men who have any knowledge of powder metallurgy. I don't want to give the impression that the technique is in any way at all difficult or unusually tricky, but it is nevertheless quite a new and unusual branch of metallurgy and in my experience the average metallurgist or chemist or engineer feels quite at sea when approaching the subject and hasn't the ghost of a notion of how to go about handling metal powders. Under such circumstances it is quite futile for any organisation not furnished with experienced staff to contemplate manufacturing immediately any selected article. The first step is to train a suitable man or men in the general technique of the subject. Powder metallurgy is partly metallurgy and partly tool and die making and in selecting suitable men this should be borne in mind. Steps should then be taken to equip a small experimental laboratory and this need not be at all expensive. Many organisations are already equipped with some sort of press but in the absence of this such a press would be the chief item of expense. It is most important that whatever press is employed it should be possible to determine with considerable accuracy the pressure employed. A suitable type would be a 100 to 200 ton hydraulic press fitted with a high speed rotary pump and a by pass valve to cut off at any preselected pressure. The type of furnace and atmosphere used depends somewhat on the types of alloys in which the manufacturer is generally interested and this will

determine obviously the temperature range of the furnace such as 1050°C. max. for brasses and bronzes and light alloys, 1200°C. max. for iron parts, or 1600°C. max. for refractory metals. For experimental work hydrogen or cracked ammonia are most generally useful and at a later date it can be decided whether a cheaper atmosphere or possibly an extremely pure atmosphere is necessary. The furnace could be quite small. A muffle 4 in. wide by 3 in. high and a hot zone 12 in. long preferably fitted with an extended water cooled zone will handle a wide variety of experiemental pressings. Some of the electric furnace manufacturers in this Country are quite experienced in designing suitable sintering furnaces. The laboratory should include besides obvious items of equipment a small mixing drum for blending together powders, possibly a small ball mill, an instrument for determining the apparent density and the flow factor of the powders used, and some equipment for measuring the particle size distribution. I would then suggest that general experimental work is undertaken in the laboratory until the staff thoroughly understand the whole technique of handling powders, pressing and sintering and are familiar with all the factors which control strength, porosity, and expansions and contractions etc., in the alloys chosen. In this connection one could not do better than to follow broadly the experimental scheme outlined in Baeza's book "A Course in Powder Metallurgy," published by The Reinhold Publishing Corporation, New York. If possible I think I would add to this the experimental production of test pieces either of full size for a normal tensile test or for pulling in the Tensometer or similar instrument. Such experiemental work should be paralleled by the investigator with a course of reading covering the whole field of published literature on the subject, which is now quite large. Norma Macdonald's recently published bibliography may be helpful in making a start.

After some months work along these lines the organisation doing such work will be in a very much better position to decide what manufacturing steps to take, and will now have a nucleus of staff which not only understands the general technique but are in a position to advise what are the possibilities and limitations of embarking upon the manufacture of any particular article. Furthermore, when it comes to purchasing high speed mechanical presses and full size sintering furnaces they will be in a position to design dies, state precisely what are the characteristics of the powders involved, specify exact pressures and say exactly what temperature-time cycles are desirable. When, however, large size plant is installed the experimental work is far from being finished and a whole series of new problems will emerge particularly connected with the die design and die wear and it will probably be necessary to commence manufacturing some article for

some time without thought of making any profit out of it. Finally, when it comes to the point of choosing some suitable article I think the best advice I can give, which I am sure is superfluous to this audience, is—Don't make anything you are not quite sure you can sell. One would say a great deal on this subject but I am sure it is not necessary. As I have already pointed out, there are broadly two types of article to choose from—one which could not be manufactured in any other way than by powder metallurgy. This is possibly at present the safer type of article to choose and if some unusual and specific property of powder metallurgy is taken advantage of there is generally not much necessity to worry unduly over costs. The other type of article is that which could be manufactured in some other way, by machining for example. This road is at present rather tricky. In general it is dangerous to employ powder metallurgy on such an article just for the sake of employing a new technique and a particularly careful investigation should be made based on the experimental production of several thousand pieces that the powder metallurgy product really is either better or cheaper than its competing article. When there is more than one road to Rome we must be careful of taking the right one.

Discussion

MR. A. W. BUCKLAND : Mr. Chairman, Dr. Jones, this is a subject on which I am very much at sea, so I stand a good chance of displaying a considerable amount of ignorance. While Dr. Jones gave us a lot of data concerning the production of those specimens after he got his powders, I am still a little in the dark as to how he would produce his powders. I wondered whether it is a balling process, or just in what manner it is carried out ? Associated with that, Dr. Jones also made the point that powder metallurgy shows a good prospect of saving metal, and that brings me back to the same point again—is there any great waste in the production of the powders ? I should have expected that quite an amount of powder would have been produced below the grain size at which he was attempting to make his powder.

DR. JONES : Metal powders are produced by many methods. Copper powder can be produced electrolytically or by reduction of copper oxide ; iron powder by electrolysis, reduction or by atomising from molten metal. If the metal is very brittle or weak, then it is frequently pulverised or ball milled. Almost any alloy that can be melted can be atomised and solders, bearing metals, brasses, bronzes, stainless steel and other alloy steels are made in this way. There

may frequently be some oversize or undersize, but generally speaking a manufacturer would not consider it a manufacturing proposition unless he got at least 80% of the type of powder he required, and even then there might be some market for the residue.

MR. J. B. SCOTT: There are two points I should like to raise. Firstly, I believe Dr. Jones said that parts with screwed threads had not been satisfactorily produced, or were not produced at all, and I should like to know why. The second point is, suppose you had a simple type of bushing which you wished to harden on the inside, would you do that hardening by mixing the powders or is it possible to apply case hardening or some such other process ?

DR. JONES: I am not familiar with any process in commercial production in which a screw thread is put on the part, and the reason is that the metal powder would not flow sufficiently in the die.

MR. J. B. SCOTT: In that way it differs from bakelite mouldings ?

DR. JONES: Yes, that is the reason. Hardened iron parts are being made and can easily be made. The hardening can be done during the sintering by introducing carbon from the atmosphere used in the sintering operation, or the iron part can be carburised by any other method.

MR. SHANNAHAN: There are three points I should like to raise, Dr. Jones. They all concern, the manufacture of Tungsten-Carbide-Cobalt alloys. In the first case, I think it is fairly well known, and we have found, that the finer the grain size the harder is the resulting compact. I should like you to tell me why this is. The second question is, in sintering these materials it is possible to over-sinter them and what happens is that we get a decrease in hardness and a decrease in porosity. We think that the deterioration is due to the running out of the Cobalt. The third question is, does the rate of cooling after sintering affect any of the properties ?

DR. JONES: I think it is quite a general case in many alloys that the finer the powder employed the harder is the resulting compact, providing the sintering temperature is the optimum one. Why that is exactly the case I doubt if anyone has yet sorted out, but it is obviously due, I should think, and is connnected with, the specific area involved. When you get down to exceptionally fine powders, the total area must be very large indeed, and if hardness is connected in any way with boundary blocking of crystal slip, then an explanation along those lines can readily be visualised. I have myself always understood that the loss in hardness in over-sintering was simply due to excessive grain growth.

MR. SHANNAHAN: The point there was that we have noticed an increase in porosity as well.

DR. JONES: I doubt if there is any real decrease in density. Probably all that happens is an increase in the maximum size of the pores caused by redistribution of theobalt. Possibly gas evolution may be an additional factor.

MR. SHANNAHAN: And the rate of cooling?

DR. JONES: I do not know.

VISITOR: Dr. Jones mentioned diamond impregnated tools. I don't know whether he could give us any information in connection with the methods employed in America for producing such tools?

DR. JONES: I do not know about America, but I can tell you about British practice. Would that be of any help to you? In most cases it is hot pressing. Lapping wheels, and particularly slitting discs and rock drilling tools are all hot pressed to my knowledge, usually in bronze or in cobalt. I understand that one of the larger firms in America producing diamond impregnated lapping wheels, makes them out of a bronze Matrix of a copper and tin powder by cold pressing followed by sintering. In this country, similar lapping wheels, I understand, are being experimentally investigated and the American technique is not considered a good one.

VISITOR: Do you know anything about the temperatures?

DR. JONES: Hot pressing in iron would be done somewhere between 975 and 1050°C.

VISITOR: Do you know the atmosphere at all, in iron?

DR. JONES: For such materials as diamond impregnated wheels, where money is no object. I should say pure hydrogen.

VISITOR: You have a small contact ring on the table there; is that a finished article straight from the press? Or has it been machined?

DR. JONES: Some of these samples of contacts have been machined after sintering..

VISITOR: What accuracy can you guarantee from the pressing?

DR. JONES: Let us take these porous bronze bushings: on this class of material up to 2 in. diameter on the simple cylindrical bushing, manufacturers in this country and in America claim a tolerance of about .002in. On the length, they are not so good, by any means, about .005 in.—007 in.

VISITOR: Could you reasonably eliminate all machining at a reasonable accuracy?

DR. JONES: There is no machining in any of these porous bronzes at all.

VISITOR: What is the difference in the wear, in quality, compared with one made from the solid metal?

DR. JONES: This is claimed to be substantially better. It is a

softer material, but has better wearing properties because it absorbs oil.

VISITOR: Therefore it is more porous?

DR. JONES: Yes. This has a porosity of about 20%.

MR. H. A. DRANE: I was rather interested in the development of the process and I would like to know a little more about the prior granulation of the powders, as in the pharmaceutical industry.

DR. JONES: Something a little similar to granulation has been used in some cases. Very fine powders do not flow, and in automatic presses they have to flow. There has been one example where two very fine powders of a different composition were heated together to diffuse one into the other and so obtained an alloy, and at the same time a coarser powder, but that technique is not likely to become popular.

MR. H. A. DRANE: I believe that the flow characteristics in the main are very poor, and what I had in mind was the suggestion that it would be possible to include oil in the compact.

DR. JONES: It has not been applied. It has been thought of, but it has not been used.

MR. H. A. DRANE: It seems an obvious way of getting over the die wear question.

DR. JONES: Don't let us mix up the two issues—materials such as graphite or paraffin are added frequently, particularly in Tungsten Carbide manufacture, to assist pressing and reduce die wear, but not from the point of view of making the powders flow.

VISITOR: I should like to ask Dr. Jones a question regarding Tungsten-Carbide. These powders can be pressed under very low pressures, but a sintered compact is obtained having negligible porosity. This is hardly possible with any other powder that I have come across, and I wonder what explanation there is to that?

DR. JONES: I think is it right to say that it is not entirely understood. It is quite a complex matter, but a reasonably satisfactory explanation has been provided by Messrs. Price, Williams and Garrard in their published work on Heavy Alloy. It occurs in circumstances where one of the phases is molten and solution and reprecipitation of the fine particles of the solid phase takes place in the liquid phase. That also occurs in Heavy Alloy, and there are also several other alloys in which it can take place.

VISITOR: Is it anything to do with fine grain sizes?

DR. JONES: Yes, certainly. I think it is definitely connected with it. To get that effect you have to use powders finer than 20 microns.

MR. JACKMAN : Mr. Chairman, there are two points I should like to raise. The first is, is there any danger of cracks occuring during the pressing operation ? The second point is on die wear ; can you give us any idea how many of those bushes, for example, we could produce from a set of dies ?

DR. JONES : Cracking is a very great difficulty. It often happens and it causes more headaches than anything else. It is more a question of die manufacture than anything else—it is one of the tricks of the trade one has to learn by experience. In connection with die wear, I would not like to give you an exact figure of when you would have to touch up a die, but in commercial practice I dont think you would get less than 10,000 out of a die set before you abandoned it.

VISITOR : On the question of gas. Have any experiments been carried out to find whether air is trapped after it has been kept under the pressure for some time ?

DR. JONES : I think I can say yes, definitely. It is well known that air is entrapped in pressing—there is no doubt about it at all.

VISITIOR : Could I then ask if it would be possible to apply a high vacuum ? Would that improve it ?

DR. JONES : It is, in fact, done.

MR. A. W. BUCKLAND : If I might ask another question, is there any amount of draw on those dies, or are they perfectly parallel ? I imagine one might have a little difficulty with ejection.?

DR. JONES : Generally, none at all.

VISITOR : DR. JONES mentioned the fact that there is both contraction and expansion on sintering. I have never heard of any case of expansion.

DR. JONES : I am not going to explain it—I could talk about that for a very long while, but it is quite frequent in bronzes for example I have known it with several alloys—I can remember it particularly in connection with silver, but I prefer not to discuss that ; it is a very long subject.

VISITOR : Is there any National Research Association which is interested in the development of Powder Metallurgy ?

DR. JONES : None that I know of : the subject has not yet apparently been recognised in academic circles.

VISITOR : Is there any difficulty with oxidation of the powders in the containers, or has that been successfully overcome ?

DR. JONES : Steel and iron powders, once having been manufactured, keep fairly well. Broadly speaking, a satisfactory iron powder would not substantially change in six months. Some powders, however, are not so good. Copper goes off fairly quickly

and lead quickly. On the other hand, aluminium powder seems to keep almost indefinitely.

VISITOR: Does it affect the properties?

DR. JONES: Yes.

VISITOR: It weakens it?

DR. JONES: Yes.

VISITOR: There is just one other question, whether powders are now manufactured on such an economic basis that Powder Metallurgy can compete with other processes?

DR. JONES: In America, yes. In this country, as far as ferrous powders are concerned, no. In this country, metal powders are being manufactured and I think practically any powder that anyone wants they can have, but up to the moment no consumer has required sufficient to justify any manufacturer putting down a large commercial plant. It is only waiting for the consumption to rise. Non-ferrous powders are, however, available in bulk at competitive prices.

MR. R. R. BRITAIN: There is one question I should like to ask. I believe Dr. Jones mentioned the fact that among the uses to which powder metallurgy could be put is that of providing a catalyst. Could you enlarge on that please?

DR. JONES: I don't know much about it, but I have had some connection with it. The product consisted of small pellets of extremely porous iron or nickel, with a porosity of some 60% or 70%, using very fine and pure powders. Why they are used and why they are good, I don't know.

VISITOR: What is the limitation on the dimensions you can produce? I assume that there is a limit—that is, if they become too bulky they probably cannot by sintered properly, that is, it would not be uniform all the way through and I suppose that castings would have an advantage over an article made by this method?

DR. JONES: I should think that that particular limitation connected with sintering is bound to be experienced sometime. The size limitation at the moment is connected entirely with capital cost of plant.

MR. A. W. BUCKLAND: What is the largest article, in the lecturer's experience, made from powder metallurgy.

DR. JONES: A porous bronze bushing of approximately 61½ lb. in weight has been made.

MR. W. J. ANSTEY: From listening to Dr. Jones' lecture to-night, I think Powder metallurgy is a subject which I will have to take an interest in, and so will all of us. Dr. Jones points out that up to date the uses of powder metallurgy are limited to articles lightly stressed There appears to me to be a field of investigation for all of us,

particularly the younger members, who I am sure will welcome a new subject which they can just dig into. It is evident that we are on the threshhold of a new technique, and we are grateful to Dr. Jones for coming down here to give a lecture to the Coventry Section. We pride ourselve that we in Coventry endeavour to give to our members the latest information and to-night the lecturer has given us up-to-date information on a subject which will in the future be of great importance. I cannot add very much to it from my own knowledge ; we use quite a number of articles made by powder metallurgy, but I have never been interested in how they are made as long as they work and cut down the costs of production. I feel that we shall all go away from here with the incentive to investigate this subject further.

MR. H. A. DRANE : Mr. Chairman, I have very great pleasure in proposing a vote of thanks to Dr. Jones.

MR. SMITH : On behalf of the Metallurgy and Chemistry Students, I must thank the Institution and Dr. Jones for giving us this lecture.

ASSEMBLING BOMBER WIRING CABLES

Paper presented to the Institution by
R. C. Willan

It is required to pass a number of cables of varying thickness into, and through, tubes made of Polyvinyl—a plastic material developed to meet the conduit requirements of the Air Ministry. These tubes vary in length ranging from several inches to something like 40 feet. The cables are, of course, slightly longer than the conduit to allow for the Plug and Socket fixing at each end, as will be clearly seen in Fig. 5.

It will be appreciated that the difficulties experienced in threading 30 to 40 feet of cables, 20 at a time, through, say, 1 in. bore Polyvinyl tubing were considerable.

In the early days the method was to pass gas piping through the Polyvinyl tubing, attaching the end to a bunch of cables and then draw them back through the conduit, a method which was

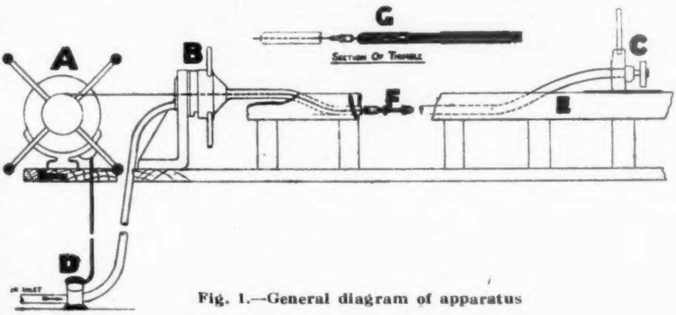

Fig. 1.—General diagram of apparatus

slow and laborious, and not altogether satisfactory, more especially on the tight assemblies. Other firms were faced with the same difficulty ; in due course, however, we contacted a firm which had been engaged on similar work for some time, and their method of handling the operation was in principle, adopted.

Description of Apparatus.

Fig. 2 shows the apparatus looking from the winding end and the operator can be clearly seen working the winding gear marked "A"

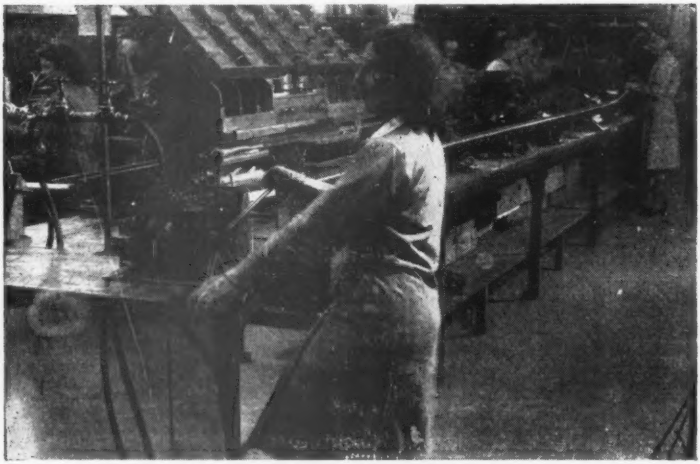

Fig. 2.—Assembly apparatus

in Fig. 1 ; " C " is an anchor for the opposite end of the conduit (Fig. 5) ; " D " is the foot control (Fig. 3) which controls the air inlet and also the brake on the winding drum ; " E " is the trough which supports the tubing ; " F " is the bullet to which the pulling cable is attached. " G " shows the cables as assembled in the thimble (Fig. 4) while being pulled through the Polyvinyl tubing.

Method of Operation.

First the length of Polyvinyl tubing is laid in the trough " E " equi-distant between fixtures " B " and " C." The bullet or piston " F " is attached to the pulling cable by a spring loaded bayonet fitting and inserted into the end of the Polyvinyl tubing nearest to fixture " B," having first made sure the conduit is laying as straight as possible in the angle iron trough. It is then clamped by fixture " B " and the remaining loose end of the Polyvinyl tubing is then held in position by fixture " C," which is purely an anchor designed to keep the tubing in place and make the apparatus safe to operate ; this fixture is not used on the short lengths. The capstan handle of the winding drum "A" is made to slide on its spindle which carries a dog clutch to enable the operator to engage or disengage the capstan handle from the drum at will. At this stage, it is necessary for the handle to be disengaged from the winding drum and also to admit air at approximately 80 lb. per square inch, through the Polyvinyl tubing. The air is filtered, cleaned

and dried before it reaches the foot control " D." This control has two functions (1) to operate the friction brake on the winding drum, and (2) to control the compressed air. On working the foot pedal the brake is released (see Fig. 3), and air is admitted into the air chamber in clamping fixture " B " and on through the Polyvinyl tubing, propelling the bullet "F" and also the pulling cable. This cable is of the finest quality obtainable, namely, Terry's 19 strand .061 dia. non-fraying tinned cycle cable.

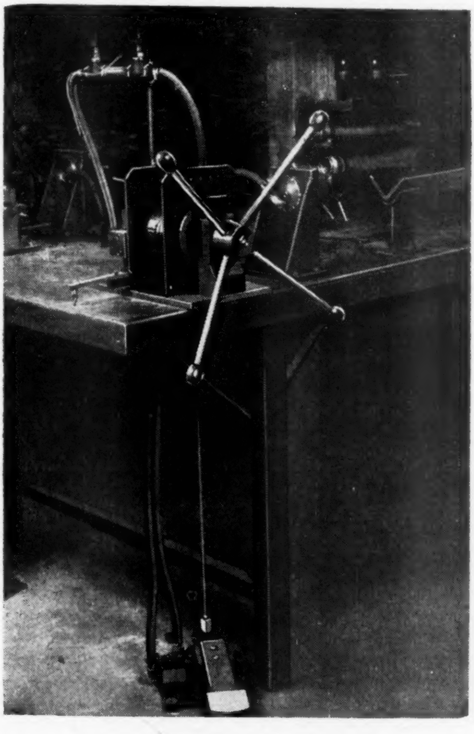

Fig. 3.—Winding gear and foot control

At fixture "C," seen in Fig. 5, a rubber buffer is fitted, against which the bullet eventually comes to rest, and it is then removed from the pulling cable. The second operator has meanwhile assembled the component cables, complete with sockets, into the thimble " G " as illustrated in Fig. 4, and it is then ready to attach to the pulling cable by means of the bayonet fitting. The cables are now ready to be pulled through the Polyvinyl tubing and it was at this stage of the proceedings that the photograph (Fig. 2) was taken. The operator seen in the foreground is ready to work the capstan handle; she engages the dog clutch on the winding spindle, presses down the foot control, which in turn releases the

friction brake on the winding gear and once again admits air into the Polyvinyl tubing and in so doing minimises the co-efficient of friction between the cables and the internal diameter of the Polyvinyl tubing. The operator then proceeds to rotate the capstan handle, which winds up the pulling cable and draws the component cables through the Polyvinyl, thus completing the assembly.

Fig. 4.—Thimble assembly

The only remaining operation is to disconnect the Polyvinyl tubing from fixtures "B" and "C," and the cables from the thimble assembly.

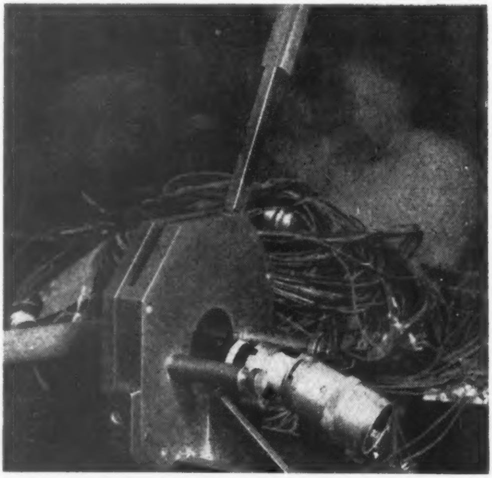

Fig. 5.—Fixture "C" showing cables assembled

The adoption of this apparently complicated method has saved considerable time on all tight assemblies and enhanced the production of a very vital part of Britain's War Effort.

Research Department: Production Engineering Abstracts

(Edited by the Director of Research).

NOTE.—*The addresses of the publications referred to in these Abstracts may be obtained on application to the Research Department, Loughborough College, Loughborough.*

ANNEALING, HARDENING, TEMPERING.

Centrifugal Quenching Machine. *(Engineering, 7th January, 1944, Vol. 157, No. 4069, p. 7, 4 figs.).*

The principle of its design is the quenching of a heated circular part from the periphery towards the centre, all parts of the periphery being immersed in the cooling oil at the same moment. The machine enables any initial faulty alignment to be corrected by adjustable pressure mechanically applied. The quenching time, the volume of the quenching medium and also its temperature can be controlled. The semi-automatic operation of the machine enables quenching to be done in about one-fifth of the time occupied by more conventional methods. The actual quenching apparatus is shown in the diagrammatic views.

Secondary Hardening of High Speed Steel Cutting Tools, by John Garland. *(Machinery, 27th January, 1944, Vol. 64, No. 1633, p. 91).*

It is necessary to emphasise the very considerable loss of cutting life, liability to chipping and actual fracture of tools which result from failure to conduct properly the secondary heat-treatment operation. Secondary hardness may be defined as the hardness developed by tempering high-alloy steels, and a secondary heat treatment, that which will bring about this secondary hardness. Interrupted quenching. Primary hardening. Secondary hardening. Testing for secondary hardness. Testing procedure.

COMBUSTION, FURNACES.

The Uses of Controlled Atmospheres in the Metal Industries. *(Sheet Metal Industries, January, 1944, Vol. 19, No. 201, p. 61, 3 figs.).*

Part IV. Non-ferrous metals. Prevention of oxidation of the metal. Type of finish. Copper. Brasses. Bronzes. Copper-nickel alloys. Nickel silvers. Magnesium alloys. Continuous mesh belt conveyor furnace. Multi radiant unit furnace. Furnace for bright annealing of sheet.

EMPLOYEES, WORKMEN, APPRENTICES.

Incentives for Indirect Workers, by Albert Ramond. *[Personnel, (U.S.A.), November, 1943, Vol. 20, No. 3, p. 154].*

While the application of incentive pay to indirect workers is likely to improve their performance substantially, the very nature of indirect work makes its control and measurement difficult. Mr. Ramond here classifies indirect workers and offers some practical solutions for the application of incentive compensation to these groups.

FOUNDRY, MOULDING, DIE-CASTING.

Hand-Operated Die-Casting Machine. (*Engineering, 14th January, 1944, Vol. 157, No. 4070, p. 25*).

The illustrated hand-operated pressure die-casting machine has been designed for the mass-production of small parts in zinc, tin, or lead base alloys. The maximum size of the die blocks is 8 in. by 5 in. by 1½ in., the normal size being 5 in. square; the die separation is 3½ in. and the maximum available casting area is 9 sq. in. The pot capacity, in zinc, is 70 lb., and the casting capacity per stroke, in the same metal is 5 oz. The machine can be successfully operated by unskilled female labour, after only a few hours' instruction, and the rate of casting can be as high as 700 parts per hour. For zinc-base alloys the melting pot temperature should be maintained between 820° and 850° F., and with antimonial-lead alloys between 600 and 630°F.

Light Alloy Foundry Technique. (*Aircraft Production, February, 1944, Vol. VI, No. 64, p. 55, 10 figs.*).

The development of metal patterns for machine moulding is an advance which has played an important part in improving dimensional accuracy and the quality of surface finish of light alloy castings. The manufacture and use of such equipment by Magnal Products, Ltd., who are specialists in this technique. Pattern manufacture. Making the moulds. Cores. Moulding. Temperature measurement.

JIGS AND FIXTURES.

Electrically-operated Chuck Jaws. (*Machinery, 13th January, 1944, Vol. 64, No. 1631, p. 47, 1 fig.*).

The opening and closing of the chuck jaws is power operated by an electric motor independently-mounted or built-in concentrically with the chuck body. When the driving motor is embodied in the chuck, electrical selection can be made for gripping the work either internally or externally and for stopping the motor at a predetermined jaw pressure.

LIGHTING.

Some Fresh Ideas on the Scope of Lighting in Industry, by J. H. Nelson. (*Sheet Metal Industries, Part 1, January, 1944, Vol. 19, No. 201, p. 101, 8 figs. Part 2, February, 1944, Vol. 19, No. 202, p. 285, 12 figs.*).

Part 1. When a job can be seen clearly, easily and comfortably, then, and only then, can it be done really well. Seeing itself is work and its efficacy depends on the operator's eyes, the job, the lighting and the decoration of the surroundings. The effects of good lighting. (1) Good lighting enables accurate work to be done. Physical limitations. The influence of field brightness. Anatomical limitations. (2) Good lighting keeps rejects down. (3) Good lighting enables one to see faster. (4) Good lighting makes seeing easy. (5) Good lighting minimises eye strain and fatigue. (6) Good lighting encourages the best use of floor space. (7) Good lighting helps cleanliness and order. (8) Good lighting improves labour conditions. (9) Good lighting promotes safety.

Part 2. The requirements of good seeing. Lighting and decoration. The "local light." The importance of contrast. Coloured light sources. The surround field. Colour of surround. Improved illumination by light finishes. Ideal surroundings.

MACHINERY, MACHINE TOOLS.

On Cutting and Hobbing Gears and Worms—Part II., by D. W. Dudley and H. Poritsky. (*Journal of Applied Mechanics, U.S.A., December, 1943, Vol. 10, No. 4, p. A.197, 7 figs.*).

Cutter required to produce a given worm. Example : straight-sided axial section worm. Cutter profile required for straight-sided axial section worm Worm-cutter deviation curve. Hobbing of gears and worms. Gear and hob axes. Example : Cutting action of hob teeth plotted in axial section of gear. Deviation of the curves from a proper straight line.

MANUFACTURING METHODS.

Steel-Tube Airscrew Blades. (*Aircraft Production, February, 1944, Vol. VI, No. 64, p. 71, 12 figs.*).

Blades from seamless tube. Honing the interior of the rough tube to remove surface blemishes to finish the inside diameter to the required tolerance. Special centreless machines used for grinding the outside diameter of the tube after rough turning. Upsetting the root-end of the tube to give greater wall thickness for subsequent machining operations on the shank. Turning the outside diameter to varying wall thickness on a copying lathe. Machining is controlled by a master cam on the rear spindle. A cage template is used for locating the defining special areas of the tube surface over which an inspection of the wall thickness is to be made. Final adjustments or " refining " of the gauge of the tube to the thickness required. Chucking mandrel. Forming the leading-edge curvature on two tubes simultaneously. Liquid is sealed inside the tube to prevent it from kinking or cracking under the pressure. Flattening the tube in an hydraulic press. During this operation liquid is allowed to escape from the interior through a valve at the top end. Tip and trailing edge of the blade are sealed in an electronically-controlled resistance welder.

Method of Grinding Crankshafts on Centreless Grinders, by E. E. Fluskey. (*Machinery, 27th January, 1944, Vol. 64, No. 1633, p. 97, 3 figs.*).

A method of grinding single-throw crankshafts on a standard centreless grinder. With this device it is also possible to grind double-throw crankshafts, also components where there are two different diameters which are to be concentric. Advantages : (1) an increase of production in the ratio of approximately 8 to 1 over a former method of grinding on a standard universal grinder ; (2) uniformity in maintaining the relation of the throw of the crankshaft pin in relation to the mainshaft ; (3) the ease of maintaining size of the crankshaft pin.

Making and Maintaining Journal Bearings, by H. Warburton. (*Mechanical World, 21st January, 1944, Vol. 115, No. 2977, p. 57, 11 figs.*).

The following factors are to be considered : (1) Selection of correct bearing metal. (2) Preparation of the shell and the pouring of the metal. (3) Suitability of the backing metal, i.e., steel, brass or cast iron shells. (4) Thickness of the lining. (5) Fit and finish of the bearing. (6) Lubrication. Melting the white metal. Arranging the bearing for pouring the white metal. Face strips. Surface finish. Precision boring. Effect of initial wear. Adhesion tests. Importance of good bonding. Lubrication. Don'ts when lining bearings.

An Introduction to High-Speed Milling, by Paul Dubosclard. [*Mechanical Engineering* (*U.S.A.*), *December, 1943, Vol. 65, No. 12, p. 865, 14 figs.*].

The production of wing spar caps made of aluminium alloy. Description of spar-milling machine. Operating results; horsepower. Spindle speeds. The author advocates the use of large cutters rather than super-high spindle speeds (over 3600 r.p.m.). Typical cutter. Vertical spindle versus horizontal spindle.

The Hercules Crankshaft, by J. A. Oates. (*Aircraft Production, February, 1944, Vol. VI, No. 64, p. 59, 22 figs.*).

Design features. Machining and assembly operations at a shadow factory.

The Formation of Sheet Metal Components by Means of the Air-Operated Drop Stamp, by A. T. Pierce. (*Sheet Metal Industries, January, 1944, Vol. 19, No. 201, p. 109, 20 figs.*).

Patterns. Moulding. The top tool. Preheating die prior to casting. Zinc alloy tools. Tool breakages. Bedding the tools. Pressing.

MATERIALS, MATERIAL TESTING.

Shipbuilding and Light Alloys, by Capt. E. C. Goldsworthy. (*Transactions of the Institution of Engineers and Shipbuilders in Scotland, January, 1944, Vol. 87, Part 3, p. 44, 7 figs.*).

Considerations arising in the use of aluminium alloys in merchant ships, to indicate some useful lines of investigation and to plead for the immediate inauguration of a programme of research. The shipbuilder demands a material which is strong, easy to work, form and assemble, yet which will give a rigid structure and stand up to marine conditions. Aluminium alloys satisfy these conditions provided the correct alloys are used. For the alloys most suitable for the construction of ships the generic term "Navalium" was coined. These non-magnetic alloys are inherently corrosion-resistant, considerably superior in this respect to mild steel. Special characteristics of aluminium alloys. Hulls. Superstructure. Value of weight saving. Examples of weight saving. The saving in weight by the use of light alloys in the superstructure alone might assist in building a better ship, the three main avenues being: (i) to increase the service availability by a reduction in displacement, (ii) to increase the earning capacity, (iii) to provide improved amenities to attract passengers. Non-structural applications. Lifeboats. Deck fittings, etc. Machinery—main and auxiliary. Characteristics of light alloys of particular marine interest. Jointing. Riveting. Welding. Corrosion. Electrolytic corrosion. Reasons for failure. Cost. Research.

MEASURING METHODS, APPARATUS.

Instrument for Measuring the Wall Thickness of Long Tubes. (*Der Deutsch Sportflieger* (*Germany*), *Vol. 10, No. 10, October, 1943, p. 164*).

The accurate measurement of the wall thickness of tubes presents considerable difficulties if the tube is of appreciable length.

The usual type of mechanical caliper gauge suffers from the drawback that any deflection of the overhung arms under gravity falsifies the measurements. Moreover it is very difficult to ensure a constant contact pressure with instruments of this nature. These difficulties have been overcome by a new type of caliper gauge designed by the Junkers firm which has given excellent results in practice and which can check the wall thickness of tubes or plates over a span up to 10 feet.

The gauge essentially consists of a U shaped feeler, one leg of which slips inside the tube and contacts the inner surface at the extremity of the limb. For this purpose the tube is supported horizontally above a parallel rail along which moves a carriage carrying two dial gauges as well as the pivoted support at the base of the U feeler. This base is provided with a balance weight by means of which the contact pressure of the inner feeler on the lower internal surface of the tube can be adjusted. Directly in line with the inner feeler but contacting on the outer surface of the tube is a second feeler attached to a spring loaded plunger moving vertically in a slide attached to the carriage. One of the two dial gauges previously mentioned is attached to this slide whilst the feeler end of this gauge contacts the second limb of the caliper gauge. The second dial gauge is supported by the carriage and records the vertical displacement of the slide. At the beginning of the test a standard distance piece is inserted between the internal feeler of the caliper gauge and the external feeler attached to the slide, both dial gauges being set to zero. The tube is then inserted and the dial gauge No. 1 will read directly the difference (+ or —) of the wall thickness from the standard dimension. Similarly dial gauge No. 2 will indicate the degree of parallelism of the outer wall with the base line. It will be noted that in this arrangement any deflection of the U shaped limbs of the caliper gauge under gravity is allowed for and that the contact pressures of external and internal feelers are constant.

(*Communicated by D.S.R. Ministry of Aircraft Production*).

Planned Production Gauging. (*Production and Engineering Bulletin, January, 1944, Vol. 3, No. 14, p. 33, 8 figs.*).

Frame system speeds inspection, reduces fatigue and protects gauges. No time is lost in handling gauges and both of the operator's hands are left free to manipulate the job. Good illustrations of many well selected examples.

Detecting Flaws in Sheets with Ultra-high Frequency Sound Waves, by A. Trost. (*Sheet Metal Industries, February, 1944, Vol. 19, No. 202, p. 255, 2 figs.*)

Ultra-high frequency (U.H.F.) sound is a means very suited for tracing discontinuities in sheets. The specimen to be tested is placed between a vibrating quartz and a wireless receiver set, running water being placed in the circuit as a coupling medium. The device is useful for speedy routine tests of the soundness of sheet.

Balancing of Rotating Apparatus—I, by R. P. Kroon. (*Journal of Applied Mechanics, (U.S.A.), December, 1943, Vol. 10, No. 4, p. A.225, 15 figs.*).

It is impossible to manufacture dynamically perfect rotors, because: (1) the material is never quite homogeneous, (2) there are always some geometrical errors, (3) the rotor may distort under operating conditions. One distinguishes "shop balancing" in which the rotor is balanced (usually at low speed) in a balancing machine, and "field balancing" which is performed on the rotor in its own bearings and at its operating speed. The vibrating system, with which we are concerned, includes, generally, not only the rotating part (rotor, spindle, shaft) but also the stationary part (stator, frame, cylinder) and often the foundations. Single disk on flexible shaft stiff bearings. Single disk on shaft with flexible bearings. Static unbalance. Rotors with distributed weight; dynamic unbalance. (a) Solid rotors. (b) Flexible rotors. Rayleigh's theorem.

MATHEMATICS, MECHANICS.

Metal Cutting Nomograph, by W. W. Gilbert and W. C. Truckenmiller. [*Mechanical Engineering (U.S.A.), December, 1943, Vol. 65, No. 12, p. 893, 10 figs.*].

Metal cutting nomographs as a simplified summary of some of the more important variables in the machining of steel. The nomographs make available some of the more important laws in metal cutting which show (1) the tool life, (2) the power required, and (3) a combined nomograph which shows the maximum output available from a given machine. The variables of machinability are as follows: cutting speed, f.p.m.; tool life, min.; constant for tool life, depending upon tool material, constant for tool life, depending upon material cut; feed, inches per revolution; depth of cut in inches; a constant for tool force, depending upon Brinell hardness of material cut.

PLASTICS, POWDER MATERIAL.

The Working of Plastics. (*The Machinist, 15th January, 1944, Vol. 87, No. 39, p. 248E, 8 figs.*).

Basic types: forms available. Thermosetting materials. Thermoplastic materials. Types of mould construction. (1) the flash mould; (2) the landed plunger mould; (3) the loading plate mould; (4) the straight plunger mould; (5) the injection mould; (6) the transfer mould; and (7) the sub-cavity mould.

Dense Nickel Parts from Metal Powder, by C. Hardy. (*Met. Progress, October, 1943, Vol. 44, No. 4, p. 634*).

Presents for the first time the results of measurements made some years ago which showed that densities up to 97% of the density of wrought Ni could be obtained by powder metallurgy methods.

(*Communicated by the British Non-Ferrous Metals Research Association*).

Powder Metallurgy of Brass. (*Metal Powder News, 10th August, 1943, Vol. 4, No. 3, p. 1*).

A short note on the pressing and sintering of brass powders containing 50-90% Cu, together with mechanical properties and densities of bars.

(*Communicated by the British Non-Ferrous Metals Research Association*).

POWER, DRIVE.

Direct-current Adjustable-speed Drives for Machine Tools, by G. A. Caldwell. (*Machinery, 20th January, 1944, Vol. 64, No. 1632, p. 69, 4 figs.*).

Starting torque thrice full-load torque. Motor started and stopped independently. Mechanical gear shifting replaced. Conventional adjustable-voltage drive with rectox exciting unit and automatic speed selection. A complete cycle of different speeds can be pre-set, and the drive will repeat this cycle with less than 5% variation, plus or minus.

SHOP MANAGEMENT.

A Guide to Personnel Counselling, Prepared under the direction of William H. Kushnick, Director of Civilian Personnel and Training. [*Personnel, (U.S.A.), November, 1943, Vol. 20, No. 3, p. 139.*].

Methods utilized. Principles. The counsellor must have information if his aid is to be effective. (1) About the employees. (2) About the plant. (3) About community resources. Counselling requires a proper setting. Counselling is by no means limited to the counselling of staff. Referral should be made to other services and agencies when necessary. The counsellor will stress preventative measures as much as possible. A counsellor must always hold the information given by employees as confidential. Relationships. to the management ; to the supervisor ; to other branches of the personnel office ; to other employee relations services ; to medical, health, safety and other related programmes ; to community agencies. Setting up and developing the programme. Counselling procedures. Interviewing. Records.

New Clauses in Labor Agreements, by James J. Bambrick, Jr. [*Personnel, (U.S.A.), November, 1943, Vol. 20, No. 3, p. 171.*]

What changes have labour agreements undergone in the first two years of war, and how symptomatic are these of trends in the collective bargaining process? In this study of 300 contracts it is shown how labour and management are anticipating the problems of demobilization by including a diversity of military service clauses in their agreements, and how problems of union responsibility, war-time strikes and production slowdowns, etc., have been approached through other clauses. A number of typical clauses are cited to illustrate the new demands being made by labour.

Dies for Drop Forging, by E. W. Mace. (*Mechanical World, 7th January, 1944, Vol. 115, No. 2975, p. 5, 3 figs.*).

Multi-impression dies for making components from bar stock. Dies for a typical small drop forging. Operations for forging a brake lever. Dies for forging a component with stepped die line.

SMALL TOOLS.

Aluminium Alloy Forging Dies, by R. F. Duff. [*S.A.E. Journal (U.S.A.), Vol. 51, No. 11, November, 1943, p. 23.*].

In the mass production of Al alloy forgings made of 145 extruded stock, the formation of blisters on the surface of the finished product has led to the rejection of an appreciable number of parts.

It was at first thought that the trouble was associated with the use of extrusions as stock material, but investigations carried out by the S.A.E. War Engineering Board have shown that blistering is also found on forgings made of standard (rolled) stock if the metal is worked too rapidly (excessive heat generated by friction in the die).

With extruded stock, the rate of deformation has therefore to be decreased and this can easily be brought about by the addition of fullers to the dies, lighter hammering, proper use of lubricants and good die finish. With these precautions, satisfactory forgings are possible, provided the original 145 material adheres to specification and especially does not contain an undue amount of silicon. A satisfactory chemical composition is given below.

Si	Cu	Mn	Mg	Al
.9%	4.40%	.80%	.40%	Rest

A satisfactory lubricant is a mixture of 50% lard oil plus 50% distillate and is applied to the die surface either by spray, swab or air blast. A small amount of graphite is occasionally added. It is interesting to note that a common cause of die failure is cracks resulting from the explosion of the die lubricant in the corners and angles of the impressions.

Die finish is of very great importance since it affects both the life of the die and the quality of the product. All angular, irregular surfaces must be avoided and the final polishing marks be in the direction of the flow of the material. The finish impression should be placed as near the centre of the die as possible and the impression cut so that the metal flow of the forging is at right angles to the grain of the die.

A die should be used for as long a run as possible (5—10,000 pieces).

It is interesting to note that the life of the normal steel die is appreciably shorter when turning out Al alloy forgings than when making steel forgings.

It is possible, however, that a new die material specially suited to the peculiarities of Aluminium forgings may be developed in the near future.

Working cold material is especially harmful to the life of the die and will also produce erratic physical properties in the forging. In this connection it should be pointed out that even under optimum conditions, the finished heat treated and artificially aged forgings made of extruded stock have a lower tensile and yield strength but greater elongations than the original extrusion after similar heat treatment and ageing. This is due to difference in grain structure of extruded and rolled 14S material leading to abnormally high values of the mechanical properties of the former after heat treatment.

The forging operation causes more recrystallisation during subsequent solution heat treatment with the result that the final mechanical properties of the forging approximate to those of the rolled rather than extruded stock.

Employment of extruded stock thus does not lead to an improvement in strength of forging but is a matter of great convenience, besides conserving forging stock for special purposes.

(*Communicated by D.S.R. Ministry of Aircraft Production*).

Quenching Dies Minimise Gear Grinding, by F. A. Paquin. (*The Machinist. 22nd January, 1944, Vol. 87, No. 40, p. 98, 5 figs.*).

In addition to deciding whether the dies should be made to the cold or hot size of the work, it is essential to work out uniform cooling of all parts of the piece. Design of quenching die in which the narrow flange and hub diameter of the workpiece cannot shrink below the required cold size, being restrained by spreaders made to the desired dimensions. Design of quenching die in which the inside diameter of the outer ring of the work is actually stretched.

STANDARDISATION.

Standardisation of Cutting Tools, by Carl J. Wiberg. [*Mechanical Engineering, (U.S.A.), December, 1943, Vol. 65, No. 12, p. 871, 21 figs.*].

Development of fine-finished, single point, chip breaker type. Standardization of high-speed steel tools. Sample page from turning tool standards. Sample page from facing tool standards. Sample page from boring tool standards. Sample page from chamfering tool standards. Sample tool drawing. Tool design investigation. Conditions and results of tests.

Cutting Angle Relationships on Metal Cutting Tools, by M. Kronenberg. [*Mechanical Engineering, (U.S.A.), December, 1943, Vol. 65, No. 12, p. 901, 5 figs.*].

Derivation of formula. Alignment charts. Alignment chart for the relationship between cutting angles for corner angle c $\leqq$ 45° and for corner angle c $\geqq$ 45°. Positive and negative maxima for the true rake angle. Derivation of the basic formula. Relationship between shear angle and true rake angle t.

SURFACE TREATMENT.

Properties of Hard Chromium Plate, by J. J. Dale. (*The Australasian Engineer, 7th October, 1943, Vol. 43, No. 329, p. 25, 13 figs.*).

Hardness and wear resistance are the most outstanding properties of this material. In addition it possesses remarkable properties of resistance to heat and corrosion. History. Deposition. Properties. Density. Melting point. Electrical resistivity. Coefficient of expansion. Hardness, wear resistance, co-efficient of friction, and a property which might be called " non-seizing tendency." Adhesion to basis metals. Strength and ductility. Corrosion resistance. Effect of heating . Grain size. Composition. Micro-structure. Effect of heating on structure. Effect of basis metal on structure. Lattice structure.

TECHNICAL INFORMATION.

The Diamond Shortage in Germany. (*Industrial Diamond Review, January, 1944, Vol. 4, No. 38, p. 4, 12 figs.*).

While Germany is searching for ways and means of working with substitutes and of replacing scarce substitutes such as sintered carbides, British and American factories, are in the main, justified to rely on the diamond itself. However, the position calls for a clear understanding of the relative merits of both the diamond and its substitutes. The forces that are acting in the truing process must be considered. Truing discs are chiefly of three kinds : (1) Smooth discs (cylindrical or conical) ; (2) Wheels of corrugated material ; (3) Discs slotted radially. The use of ceramic rollers. The use of sintered carbides. Tests were made regarding : (1) The surface quality of the ground work after truing of the wheel with various truing tools. (2) The chip volume removed from the groundwork. (3) The wear of the grinding wheel and of the truing device during the truing process. Allied engineers see how difficult it is to try to replace diamond tools in the truing of grinding wheels.

TRANSPORT AND TRANSPORT EQUIPMENT.

Transporting War Materials—Packaging Problems. (*Chemical and Engineering News, Vol. 21, No. 20, 25th October, 1943, p. 1745*).

The new package is a waterproof covering, of secret composition, but definitely a plastic, which is applied directly by spraying and which will seal off any gaps and holes. The purpose is to put a waterproof skin over metal parts and to eliminate crating. It is inexpensive and easy to apply. On medium bombers, shipped as deck cargo, use of this spray method saves 1,000 man-hours per plane over here, and 200 man-hours at the destination. Instead of crating and laboriously protecting the plane from spray, the whole airplane is covered with the plastic skin and shipped. The covering is easily removed by peeling.

Although the plastic is applied by simple spraying of a solvent solution, a definite technique must be used. If the object has openings, then spray is first directed obliquely across the surface using high pressure guns. This causes the plastic to form strings or webs across any openings. Next, a regular low-pressure spray deposits the coating over the webs already formed and the operation continues until the package is completely covered. Secret of the process, apart from the actual composition, is the rapidly drying solvent, so rapid that the plastic webs across all openings form practically immediately. The plastic shrinks upon drying, forming a skin-tight covering. To cover a medium bomber would require only 25 gallons of the solution, and at a reported cost of only a dollar a gallon, it is easily seen

that savings are coming in Army packaging. So new is the development that the first treated airplanes were, at the time of the meeting, yet on the high seas. As a test, the Air Corps dumped covered parts in Boston Harbour for five weeks just to make sure that the covering was really waterproof. Another advantage of the plastic is that there is no scarring or corrosion of precise metal parts, and though the solvent is inflammable, the plastic itself is not.

(*Communicated by D.S.R. Ministry of Aircraft Production*).

WELDING, BRAZING, SOLDERING.

Heavy Arc Welding : A.C. or D.C. ? Single- or Multi-operator ?—Part III, by H. F. Bibby. (*Mechanical World, 7th January, 1944, Vol. 115, No. 2975, p. 18, 8 figs.*).

Effect of welding load on the supply system. Details concerning A.C. installations. Sites for transformers and reactors. The low voltage distribution cables. A typical berth distribution scheme for A.C. welding with six-operator transformers. Earthing. Power factor improvement.

The Spot Welding of Magnesium Alloys. (*Sheet Metal Industries, February, 1944, Vol. 19, No. 202, p. 331*).

Weldable alloys. Preparation for welding. Surface treatment of completed assemblies. General requirements for spot welding equipment. Machine settings. Electrode pressure. Electrode type and design. Electrode pick-up. Spot welding with A.C. equipment. Spot welding with electrostatic stored energy equipment. Spot welding with electromagnetic stored energy equipment. Characteristics and properties of spot welds.

The Welding of Light Metals. (*Welding, January, 1944, Vol. XII, No. 2, p. 59, 6 figs.*).

The various methods of welding of aluminium and magnesium and their alloys. Details regarding the preparation of the parts to be joined, procedure and the equipment required.

Modern Welding Methods for Copper and Copper Alloys, by J. J. Vreeland. [*Welding Journal, (J. Amer. Weld. Soc.) October, 1943, Vol. 22, No. 10, p. 784.*]

The welding of tough-pitch Cu, deoxidised Cu, high-Cu brasses (e.g., red brass, 85% Cu), low-Cu brasses (e.g., Muntz metal and naval brass, 60% Cu), and various bronzes, using mainly the oxyacetylene and carbon arc processes. Filler rods incuded high and low Sn phosphor bronze and silicon copper.

(*Communicated by the British Non-Ferrous Metals Research Association*).

Locomotive Parts Fabrication and Welding of Bronze Bearing Surfaces, by J. W. Kenefic. [*Welding J. (J. Amer. Weld. Soc.), October, 1943, Vol. 22, No. 10, p. 799*].

Gives examples of the fabrication of new parts, the repair of cracked or broken castings, and the restoration of worn areas or moving parts. Bronze bearing surfaces are applied using either the carbon arc or metallic arc processes, and a lead bronze welding rod.

(*Communicated by the British Non-Ferrous Metals Research Association*).

Measuring Instruments for Resistance Welding Machines, by W. S. Simmie and R. F. Tylecote. (*Sheet Metal Industries, February, 1944, Vol. 19, No. 202, p. 321, 4 figs.*).

During recent years accurate control equipment has been developed for resistance welding machines, and welding times of extremely short duration are now in use. In order to obtain consistent welding results it is necessary to refer to accurate values of welding current, time and pressure. Some difficulty has been experienced in recording these values, and this report describes various instruments now in use.

Conservation of Tin in Soft Solders, by D. L. Colwell and W. C. Lang. (*Sheet Metal Industries, January, 1944, Vol. 19, No. 201, p. 84*).

Properties of several alternative solders. Faulty design is frequently responsible for service difficulties as well as for excessive use of solder by the workmen. Butt joints and simple lap joints should be avoided. Lockseam or rolled joints are stronger and in most cases lend themselves to more economical soldering techniques. Instruction of workmen. Preparation of work. Fluxes. Wiping solders. Hand-iron soldering.

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